FIRST RECORD OF REPRODUCTIVE DIAPAUSE AND AGGREGATION IN AUSTRALIAN COCCINELLIDAE (COLEOPTERA)

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Synopsis

Reproductive diapause is recorded in 5 species of Sydney Coccinellidae. *Scymnodes lividigaster* (Mulsant), *Harmonia* (*Leis*) *conformis* (Boisduval), *Coelophora inaequalis* (Fabricus), *Micraspis frenata* (Erichson), and *Leptothea galbula* (Mulsant) have a winter diapause. *S. lividigaster* also has a summer diapause. Records of aggregation in several species are listed.

Introduction

During unfavourable conditions adult Coccinellidae become dormant and some species aggregate in large numbers. Dormancy may be interpreted as either diapause or quiescence (Lees, 1955, 1956). Diapause is an adaptive arrest of development accompanied by behavioural, morphological, physiological and biochemical changes (Tauber and Tauber, 1976), which anticipates unfavourable conditions that prevent development (Lees, 1955 ; Danilevskii, 1965). Reproductive diapause is specifically concerned with gonotrophic regression and development, and the accompanying increase and decrease in fat body. In contrast, quiescence is a resting period caused directly by unfavourable environmental conditions such as low temperatures, without certain physiological changes occurring within the insect (Lees, 1956). Dormancy may be described as hibernation or aestivation, but there is much confusion in interpreting these terms.

Aggregation in Coccinellidae is always associated with diapause. It is a very specific behavioural feature, and both monospecific and heterospecific aggregations have been observed (Hagen, 1962 ; Hodek, 1973).

Although aggregation and diapause in Coccinellidae have been widely reported, there are no records from Australia. This study shows that both occur in some of the commoner Australian species.

Reproductive Diapause

During a 14 month period from the beginning of May 1975 to June 1976, weekly samples of coccinellids were collected from a reserve near Sydney. Subsequent study of these beetles has shown a reproductive diapause in a number of species. *Scymnodes lividigaster* (Mulsant), *Harmonia* (*Leis*) *conformis* (Boisduval), *Coelophora inaequalis* (Fabricus), *Micraspis frenata* (Erichson) and *Leptothea galbula* (Mulsant) were selected for detailed study. A typical female in diapause has the ovaries surrounded by prominent tracheae. The ovarioles are without vitellisation and reduced to germaria. In males diapause is more difficult to trace by examination and measurement of whole testes or seminal vesicles. Testicular follicles must be examined to determine if there has been gradual cessation of spermatogenesis. In both sexes just prior to diapause there is a massive buildup of fat body, particularly in fat droplet form. This decreases

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towards the termination of diapause. In some cases the alimentary canal is empty and filled with air bubbles.

By early May 1975, all five species had entered diapause. Throughout winter diapause was unstable, allowing beetles to become active for short periods on mild winter days without breaking the diapause. Four of the five species remained in diapause until August or early September. The fifth, *Harmonia* (*L.*) *conformis* emerged earlier at the end of July.

Scymnodes lividigaster was the only species to have a summer diapause. From September to mid October it passed through a spring generation. This was followed by a gradual increase in fat body accompanied by gonotrophic regression leading to a reproductive diapause from the beginning of November to the end of December. Unusually dry, warm weather occurred throughout this period. The total rainfall for November and December was 64 mm (daily range 0–18·6 mm), well below the normal rainfall of 158·2 mm. Temperatures were 1·2–1·7°C above the normal mean maxima and minima. These environmental conditions may have led to the disappearance of *Aphis eugeniae* van der Goot, an essential food of *S. lividigaster*, and all of these factors may have influenced the summer diapause of the coccinellid.

In contrast to the dry conditions of late 1975, the first three months of 1976 were very wet. The total rainfall was 826·2 mm (daily range 0–77·0 mm), well above the normal rainfall of 345·6 mm. *A. eugeniae* reappeared in mid January, so a plentiful food supply was associated with high reproductive activity in *S. lividigaster* until it returned to diapause in late March 1976. The other four species entered reproductive diapause between late March and mid April 1976.

Aggregation

In winter large numbers of coccinellids aggregate inside buildings, on hills, under the bark of trees or in leaf litter. Aggregating coccinellids always touch each other, each individual having its head tucked beneath part of the body of its neighbour; sometimes they are found in layers. Aggregations have been observed throughout eastern Australia and Tasmania, some ladybirds going back to the same area year after year.

The following records of aggregation have been obtained:

1. *Cleobora mellyi* Mulsant and *Harmonia* (*L.*) *conformis*. During August 1959, large numbers of beetles, mostly *C. mellyi*, were found in a dairy shed at Elliott in northern Tasmania. (Personal communication N. M. Hudson, 1975.)

2. *Harmonia* (*L.*) *conformis* and *Cleobora mellyi*. In June 1976 several thousand specimens were found aggregating beneath the bark of dead *Notophagus cunninghamii* in a eucalypt regeneration area in the Florentine Valley, Tasmania. Several live colonies consisting of some 1800 specimens were sent to the authors by Dr. H. J. Elliott. Of these 56% were *H.* (*L.*) *conformis* and 44% were *C. mellyi*.

3. *Harmonia* (*L.*) *conformis*. In April 1976, 145 specimens were discovered aggregating two metres from the ground under a piece of loose bark on a dead eucalypt, in Queen's Domain, Hobart, Tasmania. The beetles were sent to the authors by Professor V. V. Hickman (Fig. 1). Dissection of some of these specimens showed the typical morphological features of reproductive diapause.

4. *Harmonia* (*L.*) *conformis*. In April 1932, 74 specimens were found by G. F. Hill aggregating in a seedpod of *Brachychiton populneum* on Mount Mugga, A.C.T. These specimens are now in the Australian National Insect Collection, Canberra.

5. *Harmonia* (*L.*) *conformis*. In early April 1976, many hundreds of specimens were found aggregating under the bark of a dead standing eucalyptus sapling,

near Lake George, N.S.W. Similar aggregations have been observed in previous years. (B. P. Moore, personal communication 1976.)

6. *Micraspis frenata.* During winter, numbers of beetles were found on trees on a hill near Rockhampton, Queensland. (Personal communication K. Houston, 1975.)

7. *Leptothea galbula.* In June 1975, 20–30 specimens were found together on a leaf of a tree in Sylvania, N.S.W. (Personal communication M. Brunet, 1975.)

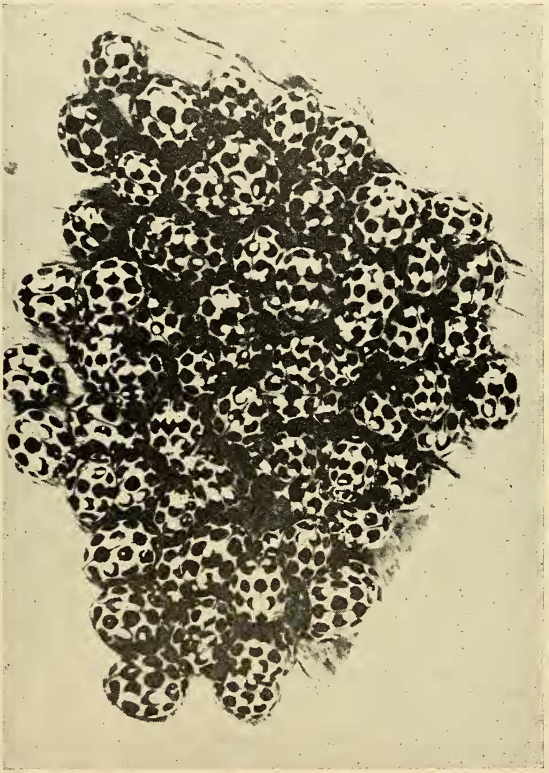

Fig. 1. Aggregation of *Harmonia* (*Leis*) *conformis* (Boisd.) on underside of eucalyptus bark from Queen's Domain, Hobart. Photo: A. M. Richards.

Three of the five reports of *H.* (*L.*) *conformis* aggregating were in April. This is not surprising, as this species enters reproductive diapause in late March.

Most Sydney coccinellids do not aggregate, but spend their winter dormancy singly or in groups of two to three under loose bark or inside the curled leaves of trees in, or quite close to, their normal summer habitat.

Discussion

Australian coccinellids exhibit many of the characteristics of temperate Northern Hemisphere species. They respond to alternation of favourable and adverse environmental and biotic conditions, and develop cycles that adapt them to their particular habitat. In the study area near Sydney, adults of all five species spend part of their life span in diapause. However in Hawaii failure to enter diapause has been recorded in *Coelophora inaequalis* (Hagen, 1962).

Winter diapause in coccinellids is related to changes in photoperiod, temperature and food supply (Tauber & Tauber, 1976). In late March and April when most Sydney coccinellids are entering diapause food is plentiful, so changes in temperature and photoperiod are more likely to be the limiting factors affecting these species. The unstable winter diapause observed in Sydney coccinellids has also been recorded in *Subcoccinella vigintiquatuorpunctata* (L) in Yugoslavia and southern England (Tanasijevic, 1958; Richards, Pope and Eastop, 1976).

There are few records of summer diapause in coccinellids. McMullen (1967a, b) records both summer and winter diapause in *Coccinella novemnotata* Herbst. He considers both are induced by variation in photoperiod, with temperature and food supply regarded as secondary factors. It is interesting that a similar condition occurs in *Scymnodes lividigaster*, but here field studies suggest that absence of essential food may be a factor controlling summer diapause. The significance of photoperiod in inducing and maintaining diapause in Australian coccinellids is currently being studied.

Ladybirds usually aggregate on prominent landmarks. They are then influenced by geotaxis and thigmotaxis, which cause them to hide in small places such as under bark or inside curled leaves (Hodek, 1973). This pattern of behaviour is followed in many Australian coccinellids. It has been suggested that chemotaxis may also be important in the formation of aggregations, but as yet there is no proof (Hodek, 1973). The same aggregation sites may be selected year after year if the general relief remains the same. This is the case with *Harmonia* (*L.*) *conformis* near Lake George in southern N.S.W.

Aggregation in Coccinellidae is important in bringing the sexes together for mating prior to dispersal. It may also protect beetles from unfavourable conditions, and in some cases from enemies (Hagen, 1962). Most published records concern winter aggregation, as do all those listed in this paper; but summer aggregation in California has also been reported (McMullen, 1967a).

There are very few records of aggregations in the Synonychini and Psylloborini (Hagen, 1962). It is therefore of interest that *Harmonia* (*L.*) *conformis* and *Micraspis frenata* belong to the Synonchini and *Leptothea galbula* and *Cleobora mellyi* to the Psylloborini.

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